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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1484

Washington, D. C. ▼ June, 1927

FACTORS INFLUENCING THE SEVERITY OF THE CRAZY-TOP DISORDER OF COTTON

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CONTENTS

	Page
History and distribution	1
Relation of stress conditions	3
Persistence of the disease in certain soil areas	4
Spot occurrence of the disorder	5
Relation of soil permeability to character and incidence of the disorder	7
Slope of land and distribution of soil moisture	8
Root development of aberrant plants	10
Relation of crop sequence to prevalence and severity of the disorder	12
Recovery of deranged plants	17
Inoculation experiments	18
Practicability of prevention or control	18
Summary	19
Literature cited	20

HISTORY AND DISTRIBUTION

An abnormal type of growth or a disorder of cotton plants began to receive notice in the Salt River Valley of Arizona in 1919. A small spot of affected plants in a field of Pima cotton near Scottsdale, Ariz., attracted the attention of one of the writers, the Maricopa County agricultural agent, and a party of two or three cotton growers while on a cotton-inspection trip in August of that year. The owner of the field reported that he had observed a few abnormal plants in the same spot in 1918. So far as is known, this was the first appearance of the disorder in Arizona. During the season of 1919 a special survey of the cotton acreage in the Salt River Valley was made by one of the writers in connection with root-rot investigations, but no evidence of the new disease was noted in any other field. Little attention was given to the disease until 1922, when it was observed in several new districts and its damaging effects were noticed by the growers. In making inquiries of growers as to whether or not the new disorder had appeared in their fields, the county agricultural agent and the writers made use of the term "crazy-top" to describe the characteristic features of the affected plants, which usually develop the greatest abnormalities of branching and fruiting in the upper parts. This term has been adopted generally by the growers for designating the disease.

Cook (*1*)[1] referred to the new disease in 1923 as possibly analogous to other growth disorders which he had studied in China and Haiti. After further observations in 1923 and 1924, he published a full description of the disease and its mode of occurrence and designated it acromania or crazy-top (*2*). Comparisons with similar disorders and malformations were made, and the possibility of its being an infectious mosaic disease distributed by insects was suggested.

It was noted from the first that the symptoms of the disease were intensified by conditions which were obviously unfavorable, and efforts were made to associate its occurrence with soil conditions, but it was soon recognized that it could not be fully explained on the basis of a simple fertility relation. The persistence of certain indications of a soil relationship, however, made it appear desirable to continue observations with a recognition of the possibility that environmental conditions might influence the disease, regardless of whether or not it was of an infectious character. Since the discovery of a mosaic disease that is carried by the soil, as announced recently by McKinney (*4*), it becomes obvious that a consideration of possible soil relations may not be out of place in an investigation where a disease of this nature is suspected or known to be involved.

A somewhat cursory survey made by the writers in cooperation with the Maricopa County agricultural agent's office[2] in November, 1925, showed that the disease was present in both Pima Egyptian and upland cotton in all parts of the Salt River Valley and that more than half of the fields were affected to some extent. It was also found in scattered areas in the Casa Grande Valley, where it was first noted in upland cotton by the writers in 1923 and identified by them as being analogous to the disorder in Pima cotton. The disease has not been found to occur along the Gila River, where the soil is deep and silty and especially favorable for plant growth. Very little of the disorder was observed in the Cave Creek delta area several miles north of Phoenix, and none was found in the Queen Creek district, which is especially noted for its favorable soil conditions.

So far as the writers have been able to ascertain, the disorder is not found except in Maricopa and Pinal Counties, Ariz. There have been no reports of its presence in other cotton-growing areas of the Southwest, and no indications of its occurence were observed by the writers in visits to the other cotton-growing sections of Arizona and California in 1924 and 1925.[3]

Although the disorder probably is of recent origin and is still localized in extent, it is already of considerable economic importance. Its disastrous effect on the yields, which can be readily observed in some fields, provides evidence that it may develop into a serious problem in cotton culture unless a better understanding of its nature and suitable control measures become available.

Since Cook has already described in detail the typical symptoms which identify the disorder, it seems unnecessary to include a descriptive treatment in this bulletin.

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[1] Italic numbers in parentheses refer to "Literature cited," p. 21.

[2] The writers are indebted to County Agent H. A. Stewart and his assistant, J. B. Duerson, for aid in locating areas of cotton affected by crazy-top in the Salt River Valley, Ariz.

[3] In September, 1926, mild manifestations of crazy-top affecting small groups of plants in fields of upland cotton were observed by one of the writers in the San Joaquin and Imperial Valleys of California.

RELATION OF STRESS CONDITIONS

Cook (*2*) has made reference to the fact that crazy-top symptoms are aggravated by stress conditions and that the extent of the injuries depends largely upon these conditions, and he has pointed out analogies in this respect between crazy-top and other disorders of the cotton plant. Several investigators of mosaic diseases noticed the effects of different conditions and that under some of these conditions the disease symptoms were partially or entirely masked. MacMillan (*5*) has shown that potato mosaic is not evident at high altitudes. Walker (*11*) observed the almost complete masking of symptoms of tobacco mosaic in midwinter and attributed this occurrence to the growth conditions of the host. Recent studies by Goss and Peltier (*3*) on the degeneration disease of potato show that many of the symptoms of the distorted growth were completely hidden in some varieties at certain temperatures of air and soil.

Although the diversity of symptoms and the limited and localized distribution of crazy-top are not inconsistent with the possibility of an infection transmitted by insects, there are also indications of a close analogy between this disorder and certain nonparasitic diseases.

Since the early observations by Cook, the disease has become more widespread, and its occurrence over a wider range of conditions has indicated that a relationship exists between the incidence of the disease and unfavorable cultural conditions. It is evident from the nature of the abnormalities that other factors are involved than those which commonly produce stress in cotton plants. Although these factors are as yet undetermined, there are indications that they are related in some manner to the condition of the soil and to the water supply. It is conceivable that peculiar physical conditions may exist in certain soil areas in these valleys and that they may produce more extreme stress reactions in the plants here than are produced in other cotton-growing regions. There is also the possibility of toxic effects from some harmful substance that has been absorbed from the soil, or of excessive accumulation of such a substance in the tissues.

Experiments of Erwin F. Smith (*10*) have demonstrated that the local application of purely physical or chemical stimuli may cause plant cells to enlarge or proliferate and that injury and death may result from their extensive application without the intervention of a parasitic organism. Rand (*8*) has pointed out that metabolic and structual changes occur in the environmental type of plant derangement.

A lack of sufficient water or soil nutrients may result in a modification of cell structure, with a tendency to reduce transpiration and to dwarf and harden the tissues. The establishment of proof in recent years of the causal relationship of infective viruses with many of the common plant disorders that were long considered of environmental origin makes it desirable to give careful consideration to the possibility of this type of disease being involved.

A disease which shows parallels with crazy-top in its relationship to cultural conditions and in some of its symptoms is pecan rosette, which Orton and Rand (*7*) and McMurran (*6*) have classed as noninfectious and noninheritable. McMurran, in describing the conditions under which it is commonly found, states that "rosette is found on soils which are for some reason ill suited to conserve moisture or to give up moisture and its content of plant food material when needed." Skinner and Demaree (*9*) found that any of the ordinary methods of increasing the supply of organic matter in soils tended to correct pecan rosette and stated that it was not definitely known whether the improved condition resulted from the additional plant food or from the greater ability of the soil to retain moisture. Rand (*8*) in 1922 concluded from study of the histology and cytology of the disease that "it bears more similarity to the known infectious chloroses than to those caused by soils or climatic factors" but presented as unanswered the question whether the factors responsible for the derangement must be introduced from without or whether they originate within the plant itself.

The limited evidence now available on the crazy-top disorder of cotton points rather to the possibility of environmental influences or to the existence of a type of contagium which does not change the structure and metabolism of plants that are functioning in a favorable environment.

The scarcity of crazy-top on fine-textured alluvial soils and the decided contrasts in the prevalence of the disease in contiguous areas that have received different cultural treatments indicate that plants which are subjected to stress conditions are more susceptible (or less resistant) to the factor or factors which produce the disorder than are plants which are continuously afforded favorable conditions for growth and development.

PERSISTENCE OF THE DISEASE IN CERTAIN SOIL AREAS

The recurrence of spots of diseased plants in the same location from year to year had been reported to the writers by various farmers, and steps were taken in 1923 to determine whether such persistence was characteristic. Two spots in a field of Hartsville cotton near Casa Grande, Ariz., and one spot in a field of Acala cotton near Mesa, Ariz., were located and recorded by actual measurement. These spots were selected because of their rather definite margins and their isolation from other areas of abnormal plants.

In 1924 and 1925 the two crazy-top spots near Casa Grande held the same relative positions as formerly, but one of them had expanded considerably in all directions. The other showed no material change on the eastern boundary and had expanded very little except on the west side. In 1925 this spot was smaller than in 1924 and the symptoms were less severe. It was noted that the soil on the east side of this spot was of a different character from that within and west of the spot, containing more sand and being much more penetrable by water and by soil-sampling tools. No diseased plants were found in the area to the east of this spot, and none were noted in another field 75 feet east of the spot and planted to cotton for the first time in 1925. The spot located near Mesa maintained its position in 1924 and 1925, but since almost the entire field had become involved, with more than 60 per cent of the plants deranged by crazy-top, the spot could be distinguished only by reason of the fact that the plants in this area were taller, with darker foliage, and were more completely sterile than the surrounding plants. This seems to indicate a greater severity or earlier incidence of the disease, so that the crop is thrown off earlier and more top growth is formed later in the season.

SPOT OCCURRENCE OF THE DISORDER

The first appearance of crazy-top in a field of cotton is usually noted in rather definite spots (pl. 1 and figs. 1 and 2), but if cotton is grown continuously, in subsequent years the area occupied by diseased plants often becomes more extensive, and in some cases the disorder spreads throughout the entire field, affecting a large percentage of the plants. The original spots of the disease can usually be identified in later years by the more pronounced symptoms. Other spots may appear with equally severe symptoms, but after a field has been affected for two or three years the diseased areas generally have less definite margins and affected plants are found mixed indiscriminately among normal plants, unless abrupt soil changes occur. Where efforts have been made by the growers to improve the cultural conditions of badly affected fields by such methods as heavy irrigations and continued cultivating, the prevalence of the disorder and the degree of injury of the affected plants have tended to diminish.

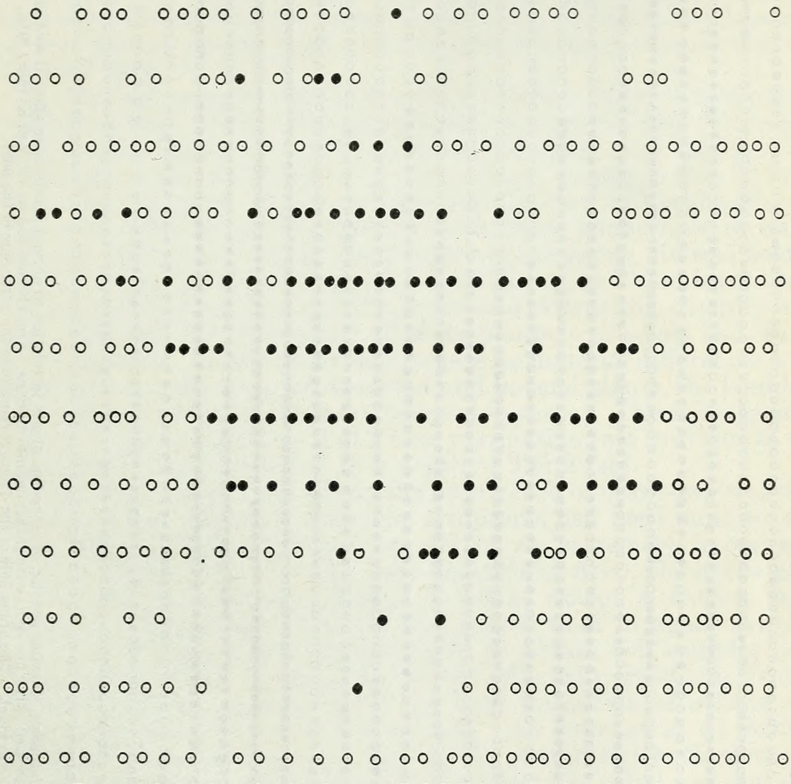


FIG. 1.—Diagram drawn to scale, showing a small definitely outlined spot of plants affected by crazy-top in a field of Acala cotton. ○=Normal plant, ●=crazy-top plant

A spot of crazy-top in a field of Acala cotton is shown by diagram in Figure 1. The limits of the affected area are seen to be rather definitely marked, and all the plants in the central portion of the spot show severe symptoms of the disease. Definite spots of crazy-top occur less frequently in Pima than in upland cotton, the affected plants usually being more or less intermingled with normal plants. The symptoms are also somewhat different in the two types of cotton, but there can be little doubt that the causal agency is the same. It has been observed that chance Pima plants in affected spots of upland cotton show the characteristic abnormalities found in Pima fields, and chance upland plants in affected spots of Pima show the characteristic distortions of growth that occur in upland plantings. Figure 2 shows diagrammatically a diseased area having definite boundaries in a field

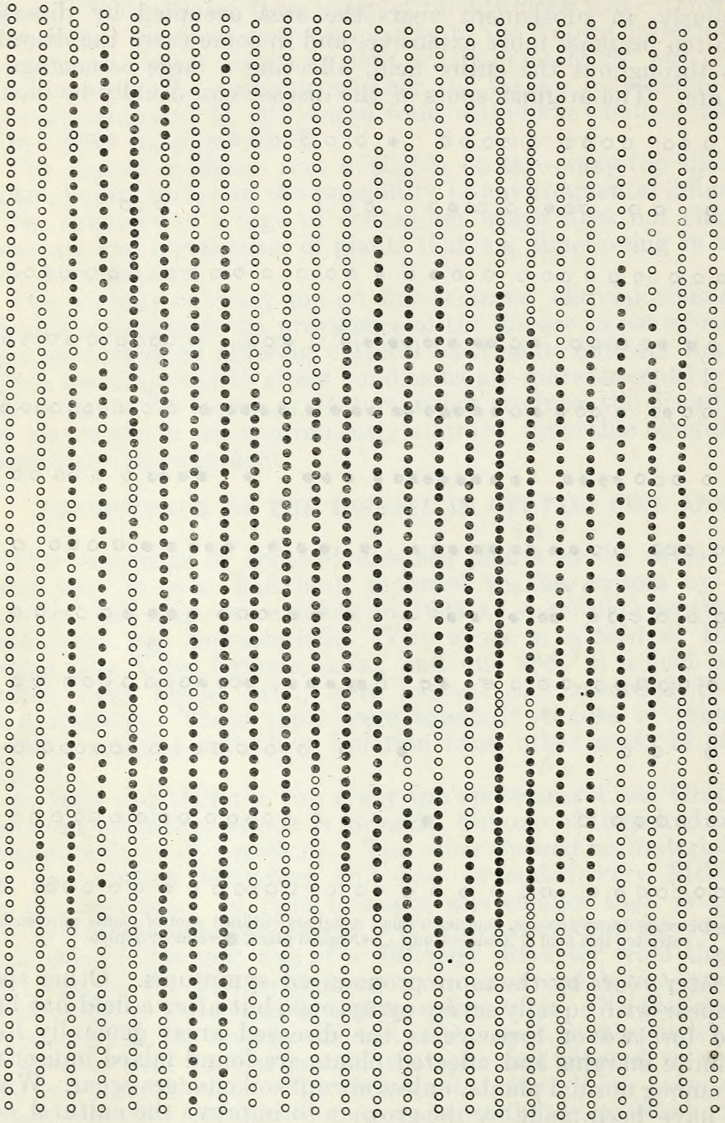


FIG. 2.—Diagram drawn to scale, showing position of crazy-top plants in relation to normal plants in an affected spot in a large field of Pima cotton which showed only a few spots with rather definite margins. Area charted 80.5 by 126 feet, Kyrene, Ariz., 1925. ○=Normal plant, ●=crazy-top plant. The upper side of the diagram represents the north side of the field

of Pima cotton; there being few normal plants within the confines of the area, an outside zone is noticeable where there is an abrupt change from diseased to healthy plants. The field as a whole was very productive, and only a few such spots were present.

RELATION OF SOIL PERMEABILITY TO CHARACTER AND INCIDENCE OF THE DISORDER

The most aggravated cases of crazy-top have been found associated with areas where the soil shows unusual cementing properties or where impervious layers occur within two or three feet of the surface of the ground. Skinner and Demaree (*9*) reported that "the unfavorable character of the subsoil is evidently an important factor in causing [pecan] rosette" and referred particularly to subsoils that are stiff and hard.

In 1923 soil samples were taken from 31 distinct spots in 9 cotton fields that were badly affected by crazy-top in the Salt River and Casa Grande Valleys. Equal numbers of borings were made in the nearest areas where all the plants were normal, usually within 200 feet of the affected spots. In seven of the fields the soil within the affected spots was definitely harder and obviously more impervious to water than the soil in areas where the plants were normal. In one field it was difficult to find large groups of normal plants, and hard layers were encountered both in the definite spots and where the disorder was only scattered. By 1925 nearly all of the plants in this field had crazy-top symptoms. In the other field, where no material differences were noted between the areas of distorted and normal plants, the land had been cropped to cotton for seven successive years. The soil was mottled with caliche materials, but a heavy irrigation just previous to the examination had penetrated to a depth of 3 or 4 feet.

At the beginning of the season the occurrence of crazy-top was first noted in areas where recently the symptoms had been most severe. These areas are characterized by soil of an extremely impervious nature. In one of these fields, near Scottsdale, Ariz., the entire area of 55 acres was severely affected in 1923, except a narrow strip bordering a canal where the soil was deeper than in other parts of the field. It was found impracticable to obtain soil samples to a depth greater than 3 feet in the worst affected part of this field in September, 1923, on account of the hard formation of caliche and decayed granite composing the subsoil. An average of 40 strokes with a 16-pound hammer was required to penetrate the third foot in the crazy-top areas, whereas the area along the canal was sampled five feet deep with ease. Deranged plants were observed in this field in late July in 1923 although the disorder was not evident in neighboring fields until late August. This field was ratooned in 1924, and the symptoms were observed on the young cotton shoots as early as May 27.

In another field near Casa Grande the impervious nature of the soil made it impracticable to obtain adequate penetration of water after July 1. The disorder was identified on the shoots of the ratooned plants on April 1, 1924, and on seedlings in the same area as early as June 11. The groups of plants growing in these obviously unfavorable locations show extreme morphological distortions of growth in the autumn and seldom set any bolls. Where there was evidence of somewhat deeper penetration of water the symptoms were more mild and a greater number of bolls were matured.

SLOPE OF LAND AND DISTRIBUTION OF SOIL MOISTURE

During the survey of the disease which was made in November, 1925, much evidence was obtained which indicated that the disease symptoms were influenced by the water supply in the soil. Several fields were observed where the only large areas of plants which were not seriously deranged were narrow strips at the lower end of the borders, where water was impounded and had sufficient time to enter the soil. (Fig. 3.)

In most cases these fields had a steep slope as well as a somewhat impervious topsoil, and it was evident that the irrigations applied after cultivations were discontinued penetrated only a few inches, except near the head ditches and at the lower end of the borders. An example of this sort is seen in Plate 2, where the normal productive plants at the lower end of the field contrast strikingly with the diseased plants at the upper end; the latter produced relatively few bolls, of which a large proportion were abnormal in some respect.

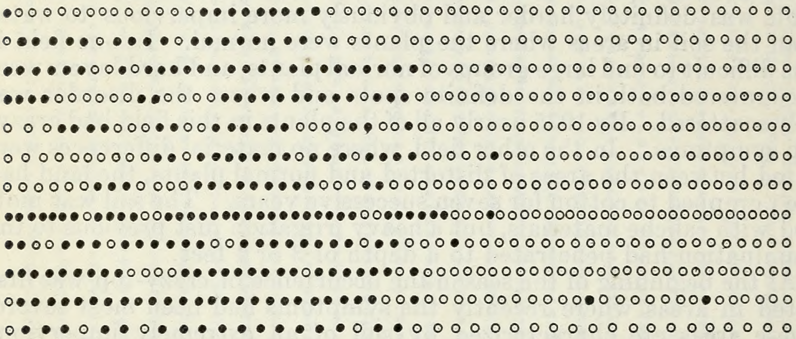
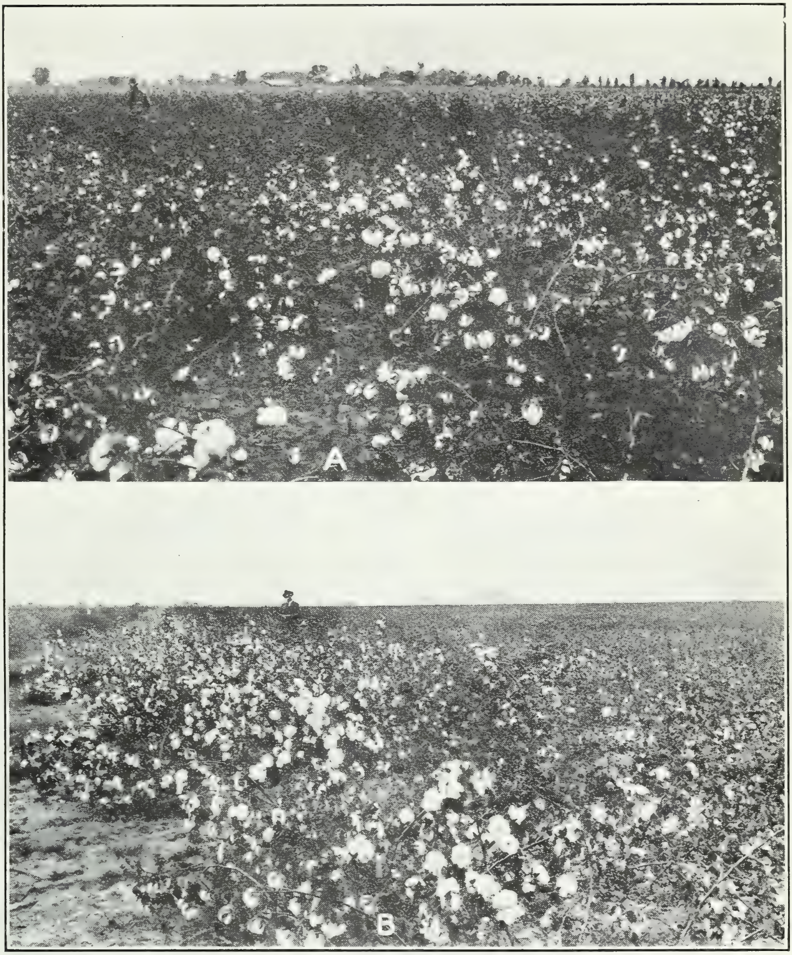


FIG. 3.—Diagram showing effect of water penetration on severity of crazy-top disorder at the lower end of a field which had a grade of about 40 feet to the mile. The diagram represents a typical section twelve 100-foot rows. It will be noted that there are only a few diseased plants in the lower 50 feet near the waste ditch. The dividing line was distinct for the quarter-mile width of the field. ○=Normal plant, ●=crazy-top plant. The right-hand part of the diagram represents the lower end of the field

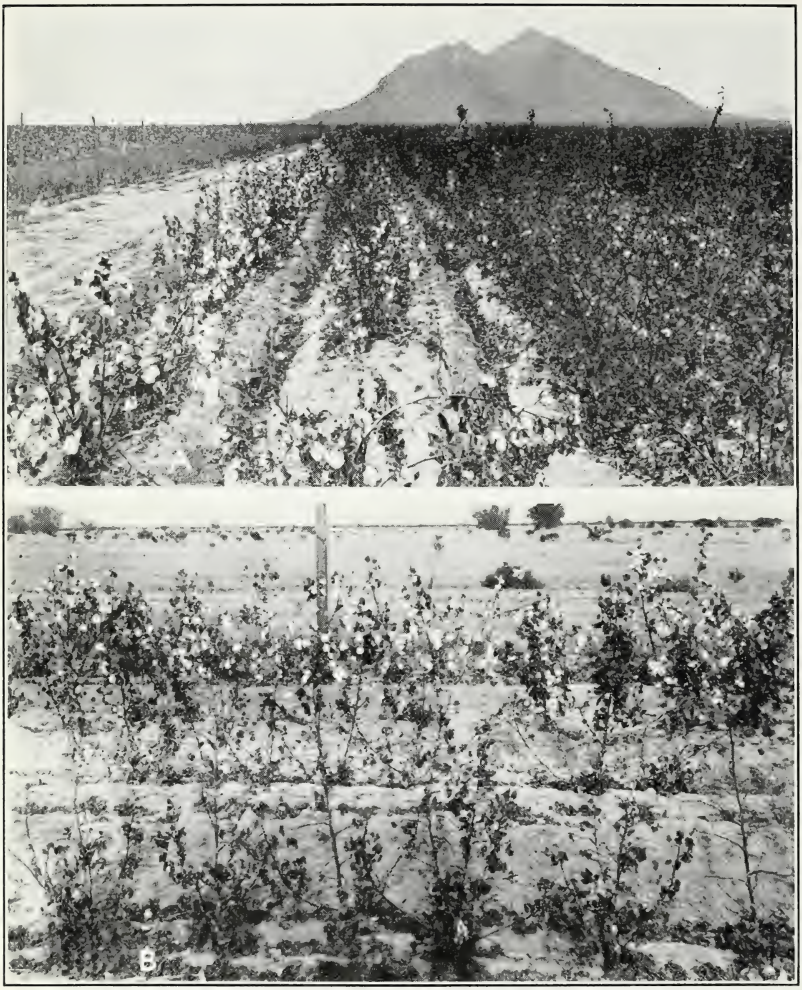
It was also characteristic of these fields with steep slope that the outside rows either were free of the disease or showed only mild symptoms late in the season, and the plants were conspicuously more productive than those inside the field, indicating the advantages which these plants undoubtedly had in obtaining moisture. Plate 2, A, shows an outer row of Acala cotton in such a field, with all plants productive, although some of them manifested the disease late in the season, while the other plants remained normal. It will also be seen that the second row in this field had fewer bolls owing to the fact that the disease affected the plants earlier and more severely. The plants in the third, fourth, and ensuing rows were still more severely affected and produced no bolls of normal size. Another example, from the same field, of the complete sterility and abnormality of the plants of the inner rows, in contrast with normal well-fruited plants in the outside row, is illustrated in Plate 2, B. The number of normal and diseased plants in several of the outer rows in 50-foot sections from each side of this field is graphically shown in Figure 4. In the outer rows many of the plants shown as affected by crazy-top pro-



AREAS AFFECTED WITH CRAZY-TOP

A.—View of a portion of a large crazy-top spot in a field of Mebane cotton. It will be noted from the difference in productiveness of the plants that the affected area is very distinct.

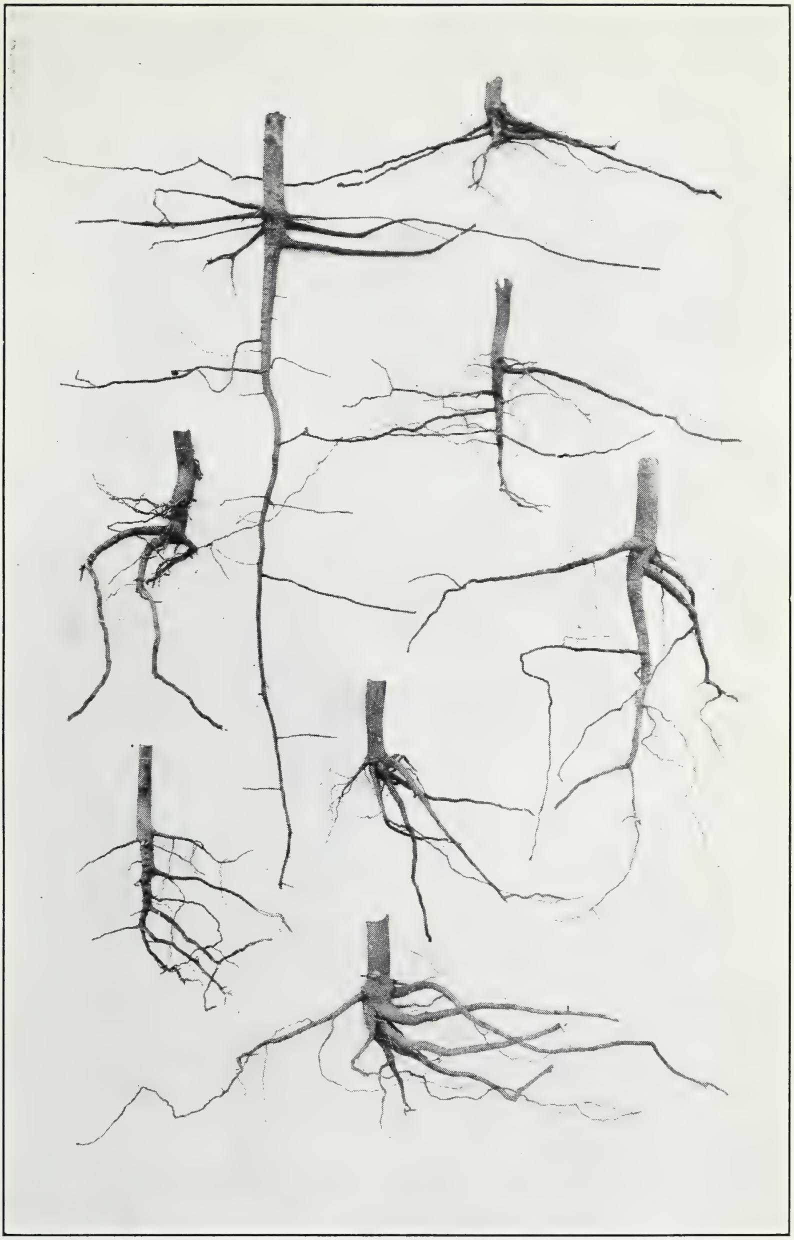
B.—Relation of water penetration to effects of crazy-top disorder. The productive plants at the left occupy an area where water was impounded at the end of the furrows. The greater part of the plants in the area at the right, where water penetration was shallow, were severely affected with crazy-top and produced few bolls



EFFECTS OF ENVIRONMENT ON SEVERITY OF CRAZY-TOP DISORDER

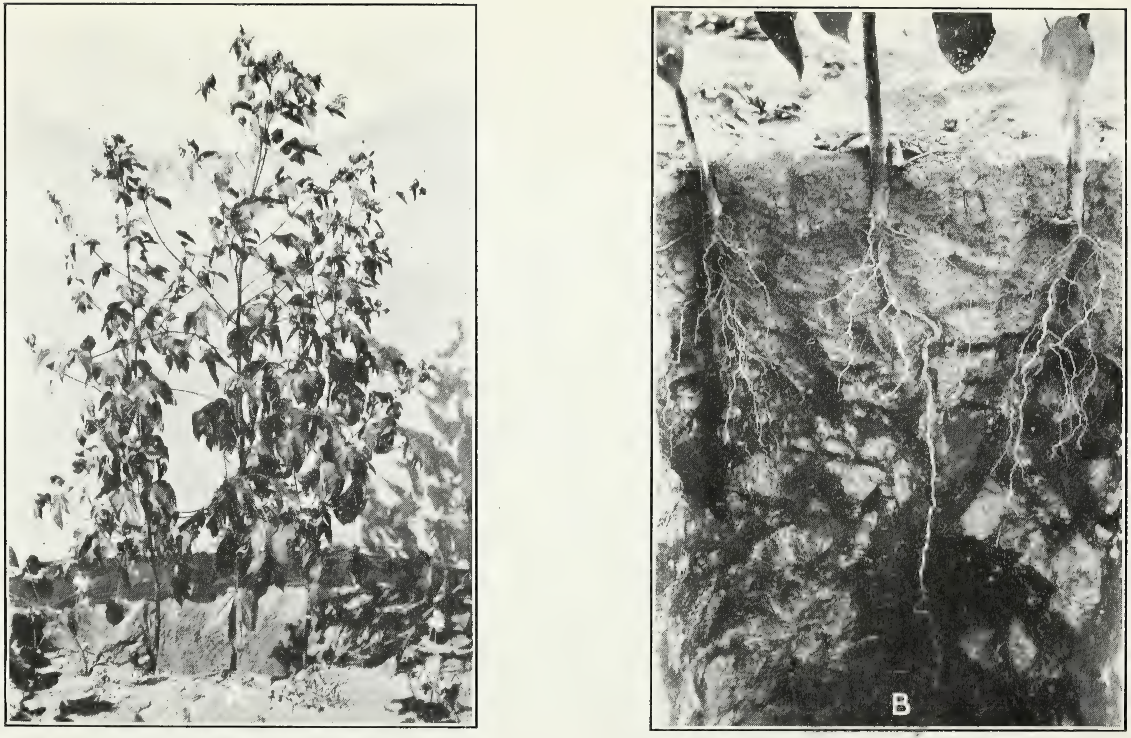
A.—The outside rows of plants, which had less competition for water than the inside rows, showed only slight effects of crazy-top, whereas the latter were nearly all affected and almost sterile.

B.—An example of the tendency of outside rows of cotton to avoid or resist crazy-top disorder while inside rows may be seriously affected



COMPARISON OF COTTON ROOT SYSTEMS FROM DIFFERENT SOILS WITH REGARD TO CRAZY-TOP DISORDER

The root system in the upper left-hand corner shows the typical rooting habit of Pima cotton in porous river-bottom soil (Pima sand at the United States Field Station, Sacaton, Ariz.), where the crazy-top disorder has never been in evidence. The seven other root systems are typical of Pima cotton plants in mesa sandy loam (McClellan sandy loam at the Sacaton seed farm), which has cementing tendencies and where the crazy-top disorder has been prevalent for at least four years. The farms are about 1 mile apart



A NORMAL PIMA COTTON PLANT BETWEEN TWO OTHER PLANTS AFFECTED BY CRAZY-TOP

A.—Appearance of plants above ground. B.—Root systems of same plants. The long taproot of the normal plant in the center penetrated deep into the soil by following a decayed alfalfa root which it entered about 7 inches below the surface of the ground. The taproots of the affected plants on either side did not penetrate beyond the 2-foot depth. More lateral roots are seen on the two crazy-top plants duced a good crop of normal bolls before the disease was manifested in the abnormal top growth of these plants. The actual number of bolls produced by each of the plants in Figure 4 is given in Table 1. The average number of bolls per plant is seen to be much greater in each of the outside rows than in any of the inner rows. The bolls in the outer rows were also much larger than those in the inner rows, the latter generally being extremely small and deformed.

TABLE 1.—*Number of bolls produced by each of the cotton plants shown in Figure 4*

[Condition of plants indicated by N (normal) and D (diseased with crazy-top)]

Order of plants in row	Condition of plant in the row, showing number of bolls for each—								
	North side of field					South side of field			
	Row 1	Row 2	Row 3	Row 4	Row 5	Row 4	Row 3	Row 2	Row 1
1	N-37	N-13	D-18	D- 0	N-11	N-19	D- 2	N-14	N-20
2	N-35	D-39	D-14	D- 0	D- 0	N-29	D- 8	D-16	N-19
3	N-28	N-11	D-13	D- 0	D- 0	N- 8	D- 5	D- 4	D- 1
4	N-62	N-28	D-12	D- 0	N- 7	D- 0	D-10	D-10	N-16
5	N-23	N-26	D- 2	D- 0	D- 0	D- 1	D- 1	D- 6	D- 8
6	N-77	N-30	N-10	D- 1	D- 0	D- 7	D- 0	D- 6	D- 6
7	N-27	D-27	N- 6	D- 0	D- 0	D-10	N- 7	D-11	N-40
8	N-12	N-19	D- 2	D- 0	D- 0	D- 7	D- 1	D-12	D-20
9	N-26	D- 0	D- 0	D- 0	D- 2	D- 3	D- 1	D- 9	N-16
10	N- 9	N-22	D- 1	D- 0	D- 1	D- 3	D- 7	D- 7	D-10
11	N-22	N-21	D- 0	D- 5	D- 0	D- 6	D- 7	D-11	N-12
12	N-38	N-11	D- 2	D- 7	D- 0	D- 2	D-11	D-11	D-26
13	N-39	N-20	D- 3	D- 1	D- 2	D- 0	D-12	D- 8	D- 5
14	N-12	N-31	D- 1	D- 0	D- 3	D- 4	D- 2	N-15	D-10
15	N-40	N- 0	D- 5	D- 2	D- 2	D- 2	D- 0	D- 9	N-20
16	N-46	D-13	D- 0	D- 1	N- 9	D- 3	D-12	D- 9	N-13
17	N-33	D-20	D- 2	D- 0	D-12	D- 0	D- 5	N-26	N-26
18	N- 5	N-29	D- 0	N- 7	N- 8	D- 4	D- 4	N-17	N-15
19	N-43	D- 2	D- 0	D- 6	N- 8	D- 4	D- 7	D- 2	N-25
20	N-65	D- 4	D- 0	D- 1	D- 3	D- 2	N- 8	D- 7	N-10
21	N-56	D- 4		D- 3	D- 2	D- 0	N-11	D- 4	N-24
22		D-33		D- 0	D- 1	D- 5	D-11	D-12	N-25
23		D- 9		D- 0	D- 3	D- 7	D- 1	D- 5	N-26
24		N-11		D- 1	D- 0	D- 0	D- 4	D- 0	N-10
25		D- 9		D- 3	D- 2	D- 7	D- 6	D-10	N-15
26		N-13		D- 7	D- 1	D- 2	D- 1	D-16	D-13
27		N-25		D-13	D- 2	D- 4	D- 1	D-19	D-29
28		N-14		N- 6	D- 0	D-12	D- 0	D-13	D-17
29		N-24		D- 1	D- 0	D- 5	D- 1	N-47	D-12
30				D- 2	D- 3	D- 5	D- 4		D- 3
31				N- 6	D- 0	D- 7	D- 2		N- 7
32				D- 1	D- 2	D- 3	D- 4		N-10
33				D- 0	D- 3	D- 0	D- 0		N-27
34				D- 1	D- 1	D- 0	D-12		D-32
35				D- 0	D- 1	D- 0			N-39
36				D- 7	D- 0	D- 0			N-18
37					D- 0	D- 0			N-18
38					N-14	D- 0			N-57
39					N- 8	D- 0			
40					D- 1	D- 0			
41					D- 1				
Total bolls	735	508	91	82	113	171	168	336	700
Average	35.0	17.5	4.6	2.3	2.8	4.3	4.9	11.6	18.4

In fields with steep gradients, several cases were noted where pairs of rows or strips of several rows were conspicuous by having nearly all plants normal and productive for the entire length of the field, whereas rows on either side showed nearly all plants aberrant and producing only a few bolls, most of which were abnormal. The writers could find no more satisfactory explanation for this occurrence than that offered by the growers, namely that a chronic leak or break in a "sub-lateral" or distributing ditch allowed this strip to absorb water for a longer period than the other rows.

ROOT DEVELOPMENT OF ABERRANT PLANTS

It having been noted that differences frequently existed in the same field between the soil in the crazy-top spots and in places where the plants were normal, a number of excavations were made to ascertain whether such differences were reflected by differences in the root development of normal and crazy-top plants.

The first excavation was made in September, 1924, in a field of Acala cotton near Mesa, Ariz. A severely affected spot of completely sterile plants surrounded by apparently normal plants had been located earlier in the season, but when the spot was visited in September the adjacent normal plants during their late growth had developed various degrees of the disorder, and this condition prevailed throughout most of the field in plants that had before appeared normal. However, a trench was dug which extended from the inside of the badly affected spot into the area where the plants showed only the mild, late-season injury. The soil below the cultivation layer in this field was rather solidly cemented together and intermixed with small deposits of caliche, and no distinct differences were apparent in the soil in any part of the trench. The severely affected plants, as well as those with only late injury, showed the influence of the tight soil by the shallow root systems. The taproots seldom penetrated below 2 feet and were frequently deflected or divided several times before reaching this depth; also there was an unusual number of large lateral roots near the surface of the ground. It was apparent, however, that the severely affected plants had shallower root systems and that the number of lateral roots was greater than with the plants outside the severely affected area. Other instances have since been observed where apparently normal plants surrounding a diseased area affected early in the season have developed crazy-top as the season progressed. It seems reasonable to attribute such delayed manifestations to the fact that the plants were in better soil conditions than were the plants earlier affected.

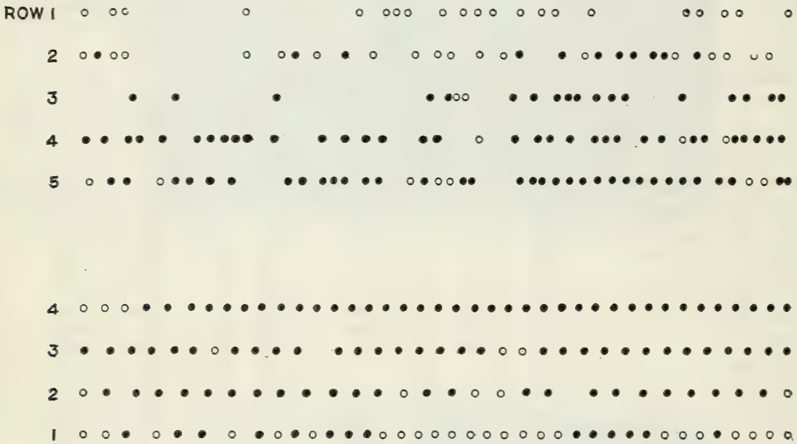


FIG. 4.—Diagram of two 50-foot sections of rows on the outside of a 40-acre field of Acala cotton. ○= Normal plant, ●=crazy-top plant. The upper section was drawn to scale from five rows at the north side of the field, and the lower section in like manner represents four rows at the south side of the field, both rows numbered 1 being outside rows. The field was one upon which cotton had been continuously grown. Note the greater number of normal plants in the outside rows

Other excavations were made where no material difference in the soil could be noted in trenches that extended from within the affected spots into the soil where the plants were normal in appearance, but in most cases when soil borings were made several feet distant from the worst affected spots, a change in the character of the soil was detected by the greater ease with which the borings were made. The root systems within affected areas were generally more abnormal than those of adjacent plants having normal tops, although the roots of the latter often were shallow and distorted, particularly in areas where the diseased plants were scattered. An extreme example of this was found in the field of Hartsville cotton near Casa Grande, referred to by Cook (*2*) and elsewhere alluded to in this paper, where crazy-top plants and near-by plants that appeared normal above ground were dug up in September, 1924, and both types were found to have remarkably stunted root systems, no taproots having penetrated below a depth of 18 inches. This spot, noted in 1923 and 1924, was present in 1925 also, but the plants showed much less injury than in either of the previous years. The grower attributed this change to the different irrigation methods practiced in 1925, which allowed a greater amount of water to enter the soil. In the fall of 1925 several affected plants were removed from this field in cylindrical cores of earth about 16 inches deep, and in no case had a taproot penetrated as far as the bottom of the core of earth.

A considerable amount of study of the rooting habits of cotton plants in connection with this disorder has convinced the writers that there is a general tendency to shallow rooting in fields where crazy-top is prevalent. This is in contrast to the deep-rooting behavior of plants in alluvial soils where the disorder has never appeared. (Pl. 3.)

An interesting phenomenon was noted at the Sacaton seed farm in connection with the relation of the root system to the growth behavior of the plant. A plot which had been occupied by a few wide-spaced rows of alfalfa plants the preceding year was planted to Pima cotton in 1924, and by the middle of the summer crazy-top symptoms began to show in many plants. By autumn the disorder was more conspicuous, and it was observed that frequently a normal, well-fruited plant would be located between two plants severely affected with crazy-top and almost completely sterile. (Pl. 4, A.) In order to study the root development of the two types of plants, two pits were dug in this plot, one exposing the roots of two crazy-top plants with a normal plant between them, and another in which two normal plants alternated with two affected plants. The soil in this plot is a coarse sandy loam and was found to be very uniform in texture to a depth of about 4 feet, where it changed abruptly to a medium-fine sandy subsoil apparently much more retentive of moisture than the surface soil. The root systems of all the affected plants were found to be shallow and confined to the upper 2½ feet of soil and with poorly developed or aborted taproots, from which extended numerous lateral roots. The taproot of each of the three normal plants had entered the decayed taproot of an alfalfa plant of the previous season at a point below where the plow had cut it off, and each had descended into the subsoil through these old roots. The taproots of the normal plants also bore fewer lateral roots than did the crazy-top plants. (Pl. 4, B.)

RELATION OF CROP SEQUENCE TO PREVALENCE AND SEVERITY OF THE DISORDER

In comparing the prevalence of the crazy-top disorder in areas cropped to cotton for several years with adjoining areas in which cotton followed a crop of alfalfa, it was noted that there were marked differences in the extent of the disease and the character of the malformations. In eight cases where the writers were able to find both conditions within the same field, the disease was found in every instance to be more prevalent and to have more pronounced symptoms in the areas cropped continuously to cotton than in the areas following alfalfa. In six of these fields, three of Pima and three of upland cotton, conditions were favorable for obtaining statistical material from a study of the plants at the immediate junction of the two areas. In four of the fields a square area 100 by 100 feet was selected at random and staked out on one side within a few feet of the dividing line, and a similar area was staked out on the other side of the line. In the other two fields, where the rows of the differently treated cotton plants lay parallel, the plats measured were also 10,000 square feet in area but were oblong rectangular instead of square. A count was made of the distorted and of the normal plants in these areas and the results tabulated. The data obtained from three fields of Pima cotton where both conditions existed are given in Table 2.

TABLE 2.—*Number of normal and crazy-top Pima cotton plants in contiguous 100-foot quadrats from areas cropped to cotton continuously and adjoining areas following alfalfa*

Row No.	Field No. 1				Field No. 2				Field No. 3			
	Cotton continuously		Following alfalfa		Cotton continuously		Following alfalfa		Cotton continuously		Following alfalfa	
	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants
1	32	19	0	37	38	37	1	28	11	17	8	28
2	24	19	0	44	32	42	6	30	13	17	4	19
3	26	10	0	44	16	58	3	37	10	8	5	29
4	30	10	0	39	22	54	2	48	16	7	7	14
5	45	7	0	39	23	57	6	29	35	11	3	21
6	49	6	0	41	24	49	3	39	51	10	12	13
7	32	7	0	35	2	53	1	34	47	4	12	31
8	40	12	0	36	15	50	6	46	51	12	26	20
9	37	10	0	47	28	51	1	43	42	10	10	25
10	29	10	0	43	28	34	4	45	29	13	14	18
11	32	17	0	41	34	22	4	37	36	9	13	31
12	24	24	0	41	15	53	2	54	29	18	19	25
13	28	16	0	40	24	48	3	35	40	16	12	30
14	35	8	0	40	22	55	3	50	16	10	15	26
15	41	10	0	47	24	41	5	39	29	10	15	33
16	28	12	2	41	17	39	3	35	24	6	12	23
17	32	13	1	62	14	33	0	35	14	18	12	31
18	18	31	0	54	22	42	1	30	20	20	17	31
19	14	43	0	49	22	26	2	36	29	16	21	26
20	11	44	0	64	19	26	1	32	11	12	17	43
21	14	40	0	55	27	36	1	51	30	18	9	34
22	12	47	0	52	15	36	1	37	13	4	11	40
23	10	42	0	81	33	27	1	53	35	4	10	41
24	13	44	0	81	32	24	1	45	49	7	17	41
25	9	42	0	51	41	40	2	47	26	4	15	33
26	9	44	0	51	25	53	0	59	43	2	11	32
27	9	41	0	65	10	46	4	32	26	5	5	24
28	10	46	0	70	21	53	2	41	46	12	9	38
Total	693	674	3	1,390	645	1,185	69	1,127	821	300	341	800
Percentage	50.7	-------	0.2	-------	35.2	-------	5.8	-------	73.2	-------	29.9	-------

It will be observed from the data in Table 2 that in all three of the fields the disease was less prevalent in the areas that had been cropped to alfalfa. In field No. 1 only three abnormal plants could be found in the twenty-eight 100-foot rows in the area following alfalfa, and the only derangement in these was the abortion of terminal buds. (Pl. 5, A and B.) In making the plant counts, any plants showing aborted terminal buds (except in the very late stages of growth) were recorded as diseased plants, although the abortion in some cases might have resulted from other causes. It is recognized that this procedure is open to criticism from the standpoint of experimental accuracy, since the abortion of terminal buds is not uncommon even in cotton plants which are grown under apparently good field conditions; but there appeared to be no other way to account for the excessive abortion of terminal buds in crazy-top fields than to ascribe a greater part of it to the same causes which produce crazy-top. In fields 2 and 3 the disorder was much more prevalent in the continuously cropped areas. Figure 5 shows the position of normal and diseased plants in sections of rows on either side of the line separating the continuously cropped area from that where cotton followed alfalfa in field 2. In field 3 there was a decided difference in the

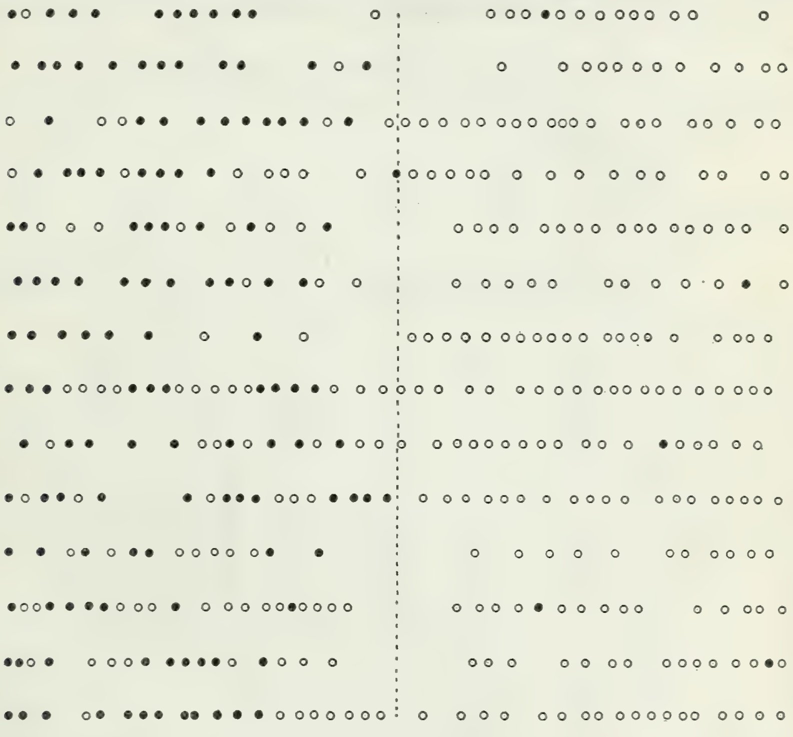


FIG. 5.—Diagram of fourteen 25-foot rows of Pima cotton on each side of the division line, field 2, between an area cropped to cotton for several years (at right) and another area in cotton the first season after alfalfa (at left). The greater number of affected plants is conspicuous in the area continuously in cotton, whereas in the cotton on the old alfalfa land but five plants are shown as affected, and the only injuries in these plants consisted of the rather early loss of the terminal buds and slight abnormalties of branching such as might follow on a plant which had lost the terminal bud by an artificial cause. ○=Normal plant, ●=crazy-top plant

character of the disease symptoms on the differently treated areas. About 73 per cent of the plants in the continuously cropped area were deranged and almost sterile. In the adjoining area, previously in alfalfa, the plants were larger and much more productive, but a considerable number had the terminal buds aborted and, although showing no other degenerative symptoms, were classed as diseased.

The data obtained from three upland cotton fields where fair comparisons could be made are shown in Table 3. In all three fields the percentage of crazy-top plants was much higher in the continuous cotton areas.

TABLE 3.—*Comparison of number of crazy-top upland cotton plants in adjacent 10,000-square-foot sections from areas cropped continuously to cotton and adjoining areas following alfalfa*

[Field 4 had 100-foot rows; field 5, 200-foot rows; field 6, 600-foot rows]

Row No.	Field No. 4				Field No. 5				Field No. 6			
	Cotton continuously 7 years		Following alfalfa		Cotton continuously 8 years		Following alfalfa		Cotton continuously 5 years		Following alfalfa	
	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants
1	26	51	6	42	76	26	7	35	106	186	19	362
2	10	55	5	39	91	28	16	59	192	192	4	407
3	20	34	7	39	84	19	14	62	109	237	7	379
4	25	45	12	29	89	15	9	64	101	253	14	407
5	22	32	10	34	98	20	23	63	102	243	26	372
6	32	33	5	47	83	23	13	93	------	------	------	------
7	19	43	3	36	108	9	7	69	------	------	------	------
8	21	40	6	21	104	18	10	95	------	------	------	------
9	35	43	6	36	87	17	17	76	------	------	------	------
10	25	44	6	32	101	21	9	97	------	------	------	------
11	26	33	5	40	85	19	13	72	------	------	------	------
12	46	27	9	42	84	17	14	73	------	------	------	------
13	37	25	13	15	85	13	12	84	------	------	------	------
14	38	23	15	25	101	13	12	67	------	------	------	------
15	31	35	7	45	89	25	11	75	------	------	------	------
16	40	30	14	30	96	29	8	80	------	------	------	------
17	30	41	8	37	------	------	------	------	------	------	------	------
18	33	28	13	31	------	------	------	------	------	------	------	------
19	21	28	8	38	------	------	------	------	------	------	------	------
20	33	29	6	42	------	------	------	------	------	------	------	------
21	29	37	6	42	------	------	------	------	------	------	------	------
22	31	39	4	43	------	------	------	------	------	------	------	------
23	35	34	7	42	------	------	------	------	------	------	------	------
24	46	22	4	43	------	------	------	------	------	------	------	------
25	41	37	5	47	------	------	------	------	------	------	------	------
26	45	30	5	47	------	------	------	------	------	------	------	------
27	34	31	6	43	------	------	------	------	------	------	------	------
28	25	45	7	42	------	------	------	------	------	------	------	------
29	32	37	5	38	------	------	------	------	------	------	------	------
30	39	27	5	42	------	------	------	------	------	------	------	------
31	58	23	7	46	------	------	------	------	------	------	------	------
32	36	35	7	40	------	------	------	------	------	------	------	------
Total	1,021	1,116	232	1,215	1,461	312	195	1,164	610	1,111	70	1,927
Percentage	47.8	------	16.0	------	82.4	------	14.3	------	35.4	------	3.5	------

That portion of field 5 which had been in cotton for eight years illustrated the most extreme stage of the disorder that was observed in the survey. Almost three-fourths of the plants in the entire area of 5 acres were seriously deranged, and many exhibited such pronounced symptoms that the field attracted notice from a distance. The typical features were the abnormally tall and spindling main stems with aborted or shortened fruiting branches and the absence of bolls on the upper half of the plants. In part of the field previously in alfalfa about 14 per cent of the plants showed abnormal top-growth characters, but all produced a good crop of bolls on the lower fruiting branches.

In field 6 a narrow road divided the two differently treated areas, and the rows nearest the road were not included in the count, owing to the stunted condition of the plants. The most common abnormalities to be found in the plants on the area following alfalfa were aborted terminal buds and divided stalks, while more than half of the plants in the area cropped continuously to cotton bore distinct crazy-top symptoms and were unproductive. The affected plants occurred both in groups and as scattered individuals throughout the entire length of the 600-foot rows.

In order to determine if there were noticeable differences in the extent of the disorder in fields of cotton the first year after alfalfa and the second year after alfalfa, a count was made in representative sections of two adjoining fields of Pima cotton that had been planted in this sequence. The data obtained are given in Table 4.

TABLE 4.—*Comparison of prevalence of crazy-top disorder in Pima cotton plants in 100-foot quadrats taken from areas planted to cotton in the first and second years following alfalfa, respectively*

Row No.	Cotton first year following alfalfa		Cotton second year following alfalfa	
	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants
1	3	33	30	47
2	2	31	24	51
3	1	31	29	55
4	6	30	25	46
5	3	37	21	48
6	6	40	7	59
7	2	33	14	50
8	4	42	14	57
9	1	25	9	63
10	2	27	13	63
11	3	39	16	59
12	2	43	4	42
13	12	31	9	51
14	2	28	18	33
15	2	36	11	45
16	0	33	13	53
17	2	31	23	54
18	2	35	8	52
19	0	40	4	47
20	0	29	4	40
21	1	27	8	43
22	2	26	3	52
23	2	36	4	50
24	3	30	5	50
25	2	28	11	64
26	4	35	7	66
27	1	26	10	57
28	1	21	6	31
29	2	30	17	31
30	2	30	11	40
Total	75	963	378	1, 499
Percentage	7. 2	--------	20. 1	--------

It will be noted from Table 4 that only 7 per cent of the plants were affected in the area in cotton the first year after alfalfa, whereas approximately 20 per cent were affected in the area planted to cotton the second year after alfalfa.

In order to determine the extent of the disorder in fields planted to cotton for the first time after several years in an uncultivated state, a count was made in a field of Acala cotton that had not been cropped since 1920, when a part of it was in Pima cotton. A corresponding area 75 feet away, in a field of Acala which had shown the disease for three years, was examined and the number of diseased and normal plants recorded. The results are shown in Table 5.

TABLE 5.—*Comparison of number of crazy-top plants in 10,000-square-foot section of field of Acala cotton affected in the same spot for the third year and area 75 feet distant in field cropped to cotton for the first time since 1920*

Row No.	Representative section of large crazy-top spot affected third successive year		Representative section of adjoining field in cotton first year since 1920	
	Crazy-top plants	Normal plants	Crazy-top plants	Normal plants
1	9	29	0	73
2	10	16	0	42
3	15	23	0	57
4	5	19	0	47
5	15	16	0	55
6	13	53	0	50
7	12	31	0	64
8	14	33	0	46
9	19	31	0	49
10	13	32	0	49
11	13	20	0	59
12	10	26	0	72
13	6	38	0	56
14	11	32	0	60
15	16	36	0	71
16	9	11	0	53
17	10	12	0	42
18	11	29	0	42
19	8	15	0	58
20	7	17	0	53
21	8	17	0	59
22	11	18	0	54
23	14	21	0	55
24	11	8	0	54
25	25	9	0	61
26	13	7	0	65
27	18	9	0	60
28	19	17	0	48
Total	345	625	0	1,554
Percentage	35.6	--------	0	--------

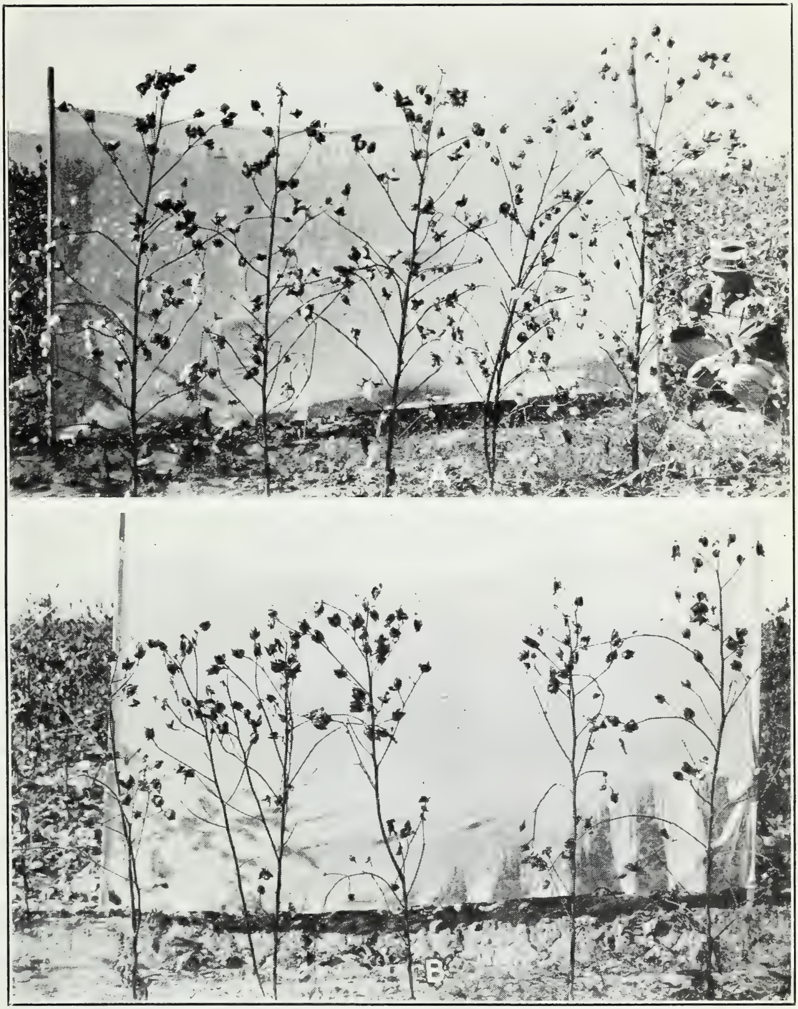
None of the plants in the 8 acres of the field newly returned to cultivation showed any crazy-top symptoms, whereas the 10-acre field which had been continuously in cotton was severely spotted with the groups of deranged plants. The surface soil in the field which lay fallow prior to cotton planting in 1925 was more sandy than that in the adjoining field where crazy-top was prevalent, and this soil difference as well as the fallowing may have contributed to the normal behavior of the plants.

The difference in productiveness of Pima plants affected with crazy-top and of those in the more favorable condition following a crop of alfalfa is shown in Table 6.

Table 6.—*Difference in productiveness of Pima cotton plants from an area cropped continuously for 4 years to cotton which was badly affected by crazy-top, as compared to an adjoining area of cotton following alfalfa*

[The plants were chosen systematically by walking diagonally across the area and selecting the plant nearest the end of every third step]

Plant No.	Number of mature bolls per plant	
	On continuously cropped area	On area following alfalfa
1	21	68
2	21	96
3	29	80
4	34	63
5	18	83
6	27	56
7	20	72
8	26	77
9	17	46
10	18	67
11	17	51
12	14	53
13	21	64
14	19	80
15	25	61
16	27	76
17	24	52
18	18	47
19	21	51
20	27	57
Average	22.2	65.0

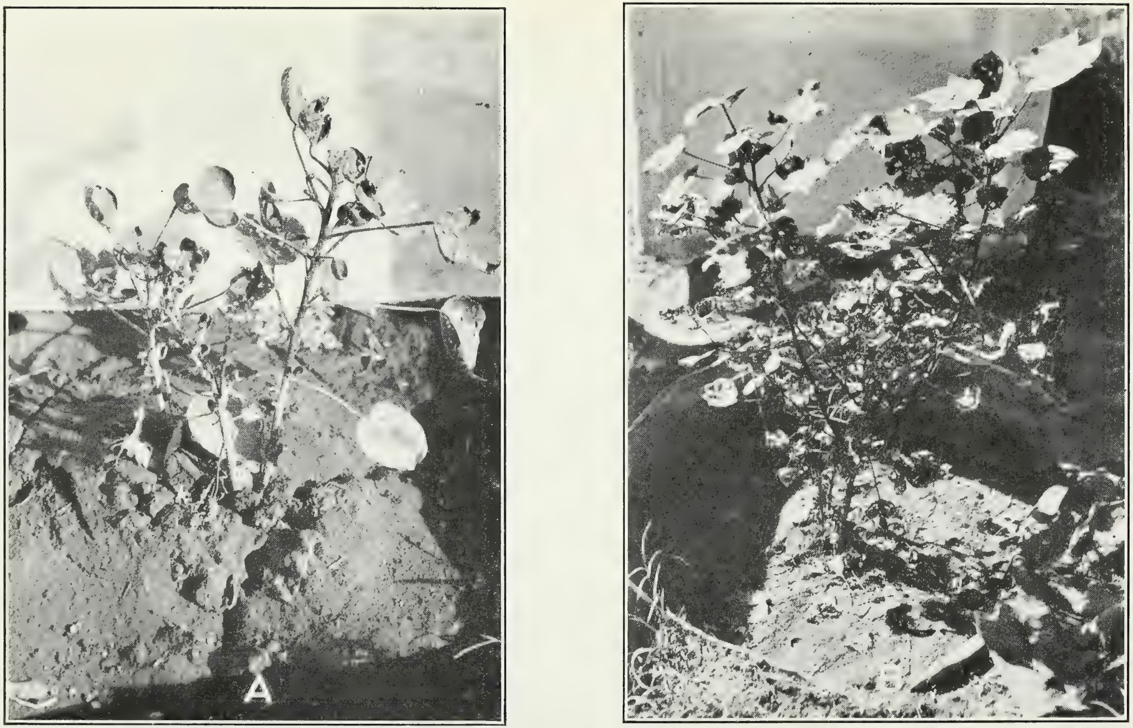


TYPICAL BEHAVIOR OF PIMA COTTON PLANTS IN ADJOINING AREAS UNDER DIFFERENT CROPPING CONDITIONS

A.—Plants in an area where cotton followed alfalfa (field 1).

B.—Plants in an adjoining area cropped to cotton three years continuously. Note the aberrant plant characters and lack of productiveness in this group and the normal habits of growth in the upper group.

These groups of plants were less than 30 feet apart and typify conditions in the differently treated parts of the field. The leaves were removed to show the branching habits and fruit



HARTSVILLE COTTON PLANTS AFFECTED WITH CRAZY-TOP

A.—Plants affected by the disorder as they appeared a few days after transplanting from a field near Casa Grande to the Sacaton field station, June 30, 1924. B.—One of the same plants, September 11, 1924, after 42 days' treatment by supplying ample irrigation water containing a small quantity of sodium nitrate. Note the normal size and appearance of the top leaves, squares, and flowers on the two vigorous vegetative branches

The mature bolls on 20 representative plants were counted in each of the 10,000-square-foot areas in one field of Pima where comparisons were being made between the section continuously in cotton and that where cotton followed alfalfa. From Table 6 it will be seen that the plants in the area where alfalfa preceded the cotton crop were nearly three times as productive as those on the continuously cropped area. The dividing line between the two treatments was distinct for the entire width of the field, because of the difference in the growth of the plants and in the number of mature bolls.

Such marked differences between continuous areas as are shown in Tables 2 to 6 indicate that the plants under favorable conditions either were not susceptible to the factor or agent which caused the derangement in the continuously cropped area, or that the effects were so masked as to be invisible. If an organic disease is involved, it seems clear that the manifestation of the disease is dependent on cultural conditions.

RECOVERY OF DERANGED PLANTS

That cotton plants affected by crazy-top may recover, at least partially, under late-season conditions and produce a fair crop of bolls in the tops of the plants has been noted by Cook and others who have studied the behavior of the disorder. Pima cotton shows more recovery than upland varieties, but under certain conditions either kind may show a return to normal characters of growth. A field of Acala cotton near Peoria, Ariz., showed a high percentage of seriously affected plants in late August, 1924, but recovery was so complete by the middle of October that a close inspection of individual plants was necessary before the effects of the disease could be noticed.

In July, 1924, four badly dwarfed and distorted Acala plants were removed from the center of a badly diseased area near Casa Grande, Ariz., by means of date-palm-offshoot transplanters. By the use of these transplanters it was found possible to remove individual plants with a core of earth about 14 by 18 inches in size and with a greater part of the root system undisturbed. These cores were placed in galvanized-iron tanks about 2½ feet in diameter, and the tanks were then filled around the cores with a silty soil of proved productive qualities. The plants were covered with insect-proof cages and were watered during the remainder of the season with rain water containing a small quantity of sodium nitrate in solution. After several weeks three of the plants were discarded on account of an infestation of leaf miners (*Bucculatrix thurberiella*), but the largest plant was retained and by September began to show a return to normal growth by producing several vigorous and rapidly growing vegetative branches which developed a healthy growth of leaves, buds, bracts, flowers, and bolls. (Pl. 6, A and B.) At the time of transplanting these plants from the affected field, four other plants of equal size and similar degree of derangement were selected near the location of each of the removed plants (within 5 feet), and these plants were tagged for further observation. At the end of the season all of these 16 tagged plants were completely sterile and showed no indications of recovering. Two untagged plants, located on the edge of one of the holes left by the removal of a plant and not refilled with soil, showed a marked degree of recovery by October and produced several bolls of normal size late in the season. It is believed that the additional moisture supplied by the water collected in this hole during irrigations influenced this recovery.

From these observations it seems apparent that increasing the water supply of the plants alleviated the conditions which induced the symptoms of crazy-top, and that the causal agent, if an organism, has the relation of a weak virus or parasite which has little or no effect upon the plants when favorable growing conditions exist.

INOCULATION EXPERIMENTS

In August, 1923, an attempt was made to determine whether the crazy-top disorder could be transmitted by injection of the sap from diseased tissues into healthy plants as is possible in some of the mosaic diseases. About 100 cubic centimeters of tissue fluid was collected from the distorted leaves, petioles, and stems of diseased Pima plants at the Sacaton seed farm and used for inoculation tests on 15 normal Pima plants in an area where no disease had occurred. The sap was rubbed into mutilations made on the roots, stems, leaves and growing buds of the healthy plants, but the later growth of all the plants was normal in every respect.

On July 18, 1924, one of the writers performed similar tests on 16 healthy plants in a field of Acala cotton near Casa Grande, Ariz. The inoculations were made under the direction of George L. Peltier, a pathologist of the Bureau of Plant Industry of the United States Department of Agriculture. Three or four cubic centimeters of the freshly expressed tissue fluid from diseased plants was injected by means of a hypodermic syringe into each of the growing terminal buds of 14 of the plants in the disease-free area. All of the leaves of two other plants in this area were rubbed with crushed leaves from diseased plants until mutilated. Although all of the 16 plants made a growth of 5 to 8 inches during the remainder of the season, no disease symptoms appeared.

In order to obtain evidence on the possibility of an organism or virus being transmitted by the soil, about 2½ cubic feet of soil was removed from a severely diseased area in the Casa Grande Valley in 1923 and transported to Sacaton, where it was packed into a trench that had been dug alongside several late-planted Hartsville cotton plants in an isolated area. The transported soil was placed in actual contact with a part of the root system of each plant, but no abnormal habits of growth resulted, nor was there any evidence of the disease in this area the following year. The results of these tests are not considered as conclusive regarding the nature of the disease, but they give further support to the view that the disease, if infectious, is not shown by plants under favorable growing conditions.

PRACTICABILITY OF PREVENTION OR CONTROL

From the information at hand it appears that the crazy-top disorder of cotton is readily responsive to control measures, since the cultural conditions exert such a marked influence on its symptoms. Rotation with alfalfa is definitely indicated as a practical measure by the striking contrasts observed between contiguous areas in the same fields, with the disease injuries so largely confined to the land that had been kept continuously in cotton. Apparently no new or expensive treatment is required, but only a better recognition of what has been urged on other accounts, viz, that it is a bad policy to keep more than half of the acreage of the Salt River Valley in cotton. The data at hand indicate clearly that the rotation of cotton with alfalfa exerts a marked influence on the extent and severity of crazy-top. With the disorder becoming more prevalent each year under the present system, the need for the adoption of better methods becomes more acute. It is not profitable to grow cotton on land that is not in condition to produce a good crop.

The importance of establishing the proper slope or grade of the land in order to obtain the most effective results in irrigating crops is another matter not fully appreciated by many of the farmers in the Salt River Valley. During the years when alfalfa was the principal crop, the problem of obtaining penetration of water to the depth of the root zone was not considered difficult. The plants themselves served to check the flow of water, and their roots provided channels and openings for the penetration of the water to the subsoil. After cotton had been grown for several years in the valley, some of the farmers began to take note of the difficulties experienced in obtaining adequate penetration of water in cotton fields during late summer, especially in fields with steep slopes, and such indications have been confirmed in the investigations of the cultural problems. The complaint is frequently heard that "three times as many irrigations are now required to produce a crop of cotton as were necessary 10 years ago," and yet only a few of the farmers have made serious efforts to remedy this condition. In many of the fields that are known to be growing worse in this respect, the conditions might be improved to a large extent by changing the direction of the water flow, by constructing more substantial and more numerous borders and cross checks, by providing a greater number of distributing ditches, and by contour bordering.

A regular rotation system with alfalfa is in itself a corrective method for obtaining better penetration and storage of water. In this connection it seems pertinent to mention that experiments at Sacaton have shown that less frequent irrigations were required by cotton following alfalfa than where cotton was the preceding crop. More water is applied to the land in alfalfa, and a greater penetration of the water is obtained, so that more water is stored in the soil and the root zone is deepened. These conditions accruing during the growth of the alfalfa crop are advantageous to cotton when that crop succeeds the alfalfa. When the growers give serious attention to cultural methods that promote the deep rooting of the cotton plants and thus provide for a supply of soil moisture at all times during the fruiting period, the cotton plants respond with greater production and do not show the abnormal behavior associated with the crazy-top disorder.

SUMMARY

A new disorder of cotton plants began to attract attention in the Salt River Valley of Arizona in 1919 and became so prevalent in the seasons of 1924 and 1925 as to cause serious financial losses to the cotton growers, on account of the sterility of the plants and the resulting low yields.

Since the first description of the disorder by Cook, in 1923, its occurrence over a wider range of cultural conditions has afforded evidence that the crazy-top injuries are closely associated with unfavorable cultural conditions which produce stress effects in the plants. Although there are symptoms which are distinct from any of the ordinary stress conditions observed in cotton plants in other regions, the extent of injury is so definitely determined by the conditions that cultural methods are indicated as a practical treatment for the disease.

A comparison of areas cropped to cotton for several years with adjoining areas where cotton followed alfalfa showed either a complete absence of the disease or only a few slightly affected plants on the land previously in alfalfa, while the areas cropped continuously to cotton showed a large proportion of affected plants, many of which were seriously deranged.

The recovery of disordered plants when favorable growing conditions were restored and the failure of preliminary attempts to inoculate healthy plants indicate that the disease is of such a character that its development is caused by poor cultural conditions rather than by infection. Although the close relations with stress conditions suggest that the disease may prove to be of a physiological character, careful study should be given to the possible existence of an infective principal whose injurious effects may be in evidence only when the plants undergo stress conditions, although definite injuries may be shown in plants that grow to large size before the end of the season.

The association of the more striking and serious injuries with cemented soils, impervious soil strata, steep grade of land, and areas continuously cropped to cotton for several years would indicate that these factors have some influence on the incidence of the disease as well as on its severity, but do not offer conclusive evidence regarding the nature of the disease.

Fewer diseased plants and milder symptoms were observed on the outside rows and at the lower end of fields with steep gradients than on the inside area, indicating that an increased supply of moisture or a more regularly available supply was a controlling factor in such fields.

Rotation with alfalfa or modified methods of irrigation which bring about deeper penetration of water and a more constant supply of available moisture in the lower root zone would appear to be the most practical measures for controlling the disease.

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